RESEARCH DEPARTMENT

Television co-channel interference: the effect of the polarity of modulation

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TELEVISION CO-CHANNEL INTERFERENCE: THE EFFECT OF THE POLARITY OF MODULATION

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SUMMARY

If the frequency difference between the vision carrier frequencies of two co-channel television stations is correctly chosen, the visibility of the interference pattern is reduced to a minimum. In this case, the frequency difference (usually termed the offset) must be maintained with considerable precision; the method of operation is termed "precision offset".

In this report it is shown that the residual interference pattern visible under precision offset conditions (known as the "secondary pattern") is made less obvious if the polarity of modulation of the wanted signal is negative rather than positive.

1. INTRODUCTION

The subjective effect of co-channel interference in television can be considered as comprising three separate components. The first in importance is conveniently termed the "primary pattern"[1] and is produced by the beat frequency between the wanted and interfering vision carriers. As the frequency difference between the wanted and interfering carriers (usually termed the "offset") is increased (but not to such an extent that it exceeds the maximum modulation-frequency of the wanted system) the pattern assumes a very fine structure and is greatly reduced in visibility. However, a large frequency offset is often undesirable, from the practical point of view, and it is more convenient to take advantage of the fact that the visibility is also greatly reduced if the offset is related to the line and picture scanning frequencies of the wanted signal by the relationship:

$$\Delta f = mf_L \pm (2n + 1)fp$$

where $(2n + 1)\ fp < f_L/2$

Δf is the offset

f_L is the line scanning frequency of the wanted signal

fp is the picture frequency of the wanted signal

m and n are integral numbers.

In this case (known as the "precision offset"[2] condition) corresponding areas of the interference pattern reverse in brightness in successive fields and the retentivity of the human eye causes partial cancellation of the interference pattern. The reduction in visibility of the primary pattern by this means can be equivalent to a reduction of 20 dB in the amplitude of the interfering carrier for 405-line, 50 fields per second reception, 25 dB for 625-line, 50 fields per second reception and 26 dB for 819-line, 50 fields per second reception.[1]

The second component of the interference is the "subsidiary primary pattern"[1] which is produced by beats between the wanted vision carrier and the interfering sidebands. If the interfering signal has the same line and field frequencies as the wanted signal these subsidiary patterns will be reduced in visibility by the same offset relationship that affects the primary-pattern visibility. In this case, therefore, the subsidiary primary pattern is not of importance.

The third component of the interference, in order of visibility, is the "secondary pattern"[1] which is produced by rectification, in the receiver, of the beat-frequency components that give rise to the "primary" and "subsidiary primary" patterns. This rectification occurs principally at the detector and the cathode-ray tube (c.r.t.) of the receiver. It is of interest to note that even a detector giving an output linearly proportional to the r.f. envelope will give rise to rectification, since it cannot respond to the change of phase produced by the addition of the wanted and unwanted signals. In addition, the cathode-ray-tube brightness is not linearly related to the grid-to-cathode voltage difference and further rectification therefore occurs.

In this report it is shown that if the receiver is designed for positive modulation, the two rectification effects due to the detector and the c.r.t. are additive but, if the receiver is designed for negative modulation, the two effects tend to cancel each other. Thus if the "primary" and "subsidiary primary" interference patterns are reduced to minimum visibility by a suitable choice of the offset, the visibility of the residual pattern (the secondary pattern) will be less for a negative-modulation receiver than for a positive-modulation receiver.

2. THEORETICAL CONSIDERATIONS

The wanted signal can be considered to be a steady carrier, $c \sin \omega t$, whose amplitude, c, can be adjusted to produce any desired brightness between black and white on the c.r.t. screen. The interfering signal, with an offset $\omega_0/2\pi$, can be represented by a second carrier, $u \sin(\omega + \omega_0)t$, where the effect of modulation can be examined by adjusting the value of "u". For convenience the values of u and c are assumed to be those at the detector input and at this point the wanted and unwanted signals can therefore be expressed as a function $f(t)$ representing a carrier at the wanted frequency $(\omega)/2\pi$ modulated both in amplitude and phase:

$$f(t) = R \sin(\omega t + \phi) \tag{1}$$

$$\text{where } R = [c^2 + u^2 + 2uc \cos \omega_0 t]^{\frac{1}{2}}$$

and

$$\tan \phi = \frac{u/c \sin \omega_0 t}{1 + u/c \cos \omega_0 t}$$

If an ideal linear envelope detector is used, the video output voltage will be proportional to R. In practice the ratio u/c will be small compared with unity and terms of order greater than u^2/c^2 can be neglected giving

$$R = c + u^2/4c + u \cos \omega_0 t - u^2/4c \cos 2\omega_0 t \qquad (2)$$

It will be noted that due to the interference the mean value of R is increased by the amount $u^2/4c$ and that, in a positive-modulation receiver, this will result in an increase of c.r.t. brightness; in a negative-modulation receiver, however, a reduction of brightness will result. The further rectification of the video signal, due to the non-linear brightness/voltage characteristic of the c.r.t., must now be considered. The characteristic of the c.r.t. can be expressed with sufficient accuracy by the relationship:

$$B = kE^{\gamma} + B_0 \qquad (3)$$

where k is a constant,

γ is 2·5,

B is the brightness produced by the grid-to-cathode voltage E,

and

B_0 is the brightness of the "black" areas of the picture which is mainly determined by the ambient illumination of the room since the c.r.t. has a reflecting surface.

It is known that, to a sufficient degree of approximation, the subjective effect of the interference is directly related to the proportional change of brightness, caused by the interference, and this is given by:

$$\frac{\Delta B}{B} = \frac{(E + \delta E)^{\gamma} - E^{\gamma}}{E^{\gamma} + B_0/k} \qquad (4)$$

where ΔB is the change of brightness caused by the interference and δE is the change of grid-to-cathode voltage due to the interference.

With positive modulation, the picture information is contained within a range of carrier amplitudes from 30% (black level) to 100% (peak white). If, therefore, the value of E corresponding to peak white is taken as unity, the values E and $E + \delta E$, with c in the range $0{\cdot}3 \leqslant c \leqslant 1{\cdot}0$, are given by:

$$\left.\begin{aligned} E &= 1{\cdot}43\ (c - 0{\cdot}3) \\ E + \delta E &= 1{\cdot}43\ (R - 0{\cdot}3) \end{aligned}\right\} \qquad (5)$$

In the case of negative modulation, black level may be taken as 75% of the maximum carrier amplitude and peak-white level as 5%. If the maximum carrier amplitude is taken as unity the values of E and $E + \delta E$, with c in the range $0{\cdot}05 \leqslant c \leqslant 0{\cdot}75$, are given by:

$$\left.\begin{aligned} E &= 1{\cdot}43\ (0{\cdot}75 - c) \\ E + \delta E &= 1{\cdot}43\ (0{\cdot}75 - R) \end{aligned}\right\} \qquad (6)$$

From equations (2), (4), (5) and (6) an expression for the proportional change of brightness corresponding to any level of wanted picture brightness and any level of interfering signal can be calculated for either positive or negative modulation. The expression for fractional change of brightness is:

$$\frac{\Delta B}{B} = \frac{\pm 1{\cdot}43\gamma E^{\gamma-1} u^2/4c + 1{\cdot}43^2/4\ \gamma(\gamma - 1)\ E^{\gamma-2} u^2}{E^{\gamma} + B_0/k} \qquad (7)$$

where the positive and negative signs preceding the first term of the numerator apply to positive and negative modulation respectively, and "c" is defined by equations (5) and (6) respectively.

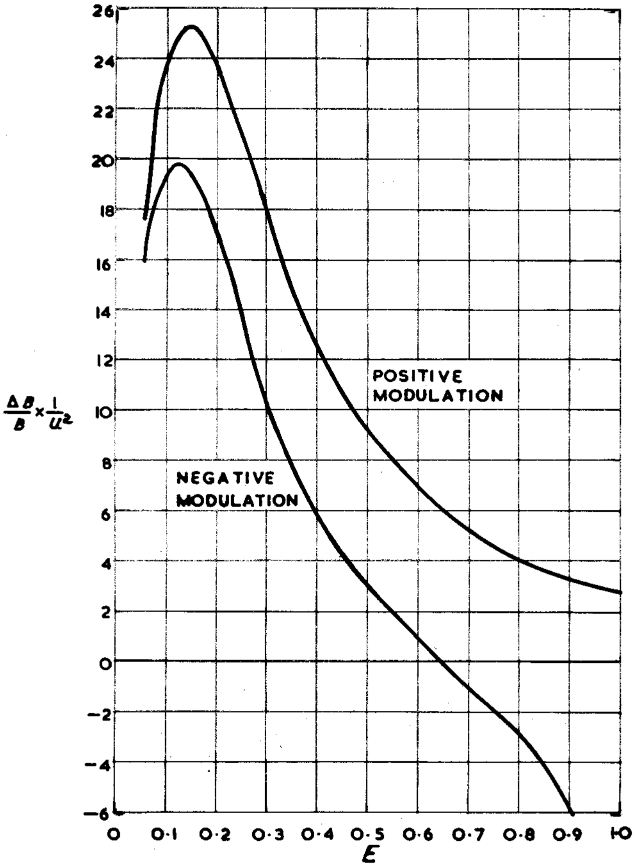

Fig. 1 - Fractional brightness-difference produced by c.w. interference

u = Ratio between unwanted-signal amplitude and maximum amplitude of wanted carrier (measured at input to detector)

E = Picture signal at input to display tube, normalized to unity at peak-white

In equation (7), sinusoidal fluctuations of brightness, due to the "a.c." terms in equation (2), are neglected. This is in accordance with the assumption that all such brightness fluctuations will be of negligible visibility, since ω_0 is chosen to give precision offset conditions. It will be seen that equation (7) is a function of u (the amplitude of the unwanted signal) and will thus vary with u. A quantity independent of u can, however, be derived by dividing equation (7) by u^2 and this quantity can be calculated and then, by appropriate multiplication, used for numerical evaluation of any particular ratio of unwanted to wanted signal.

The quantity $\Delta B/B \times 1/u^2$ is plotted in Fig. 1 for a value of B_0 equal to 1/40th of the maximum value of B (i.e. B max., corresponding to $E = 1$). Owing to the choice of units for c and E in equations (5) and (6), the quantity "u" is in fact the ratio (measured at the input to the detector) between the amplitude of the unwanted signal and the maximum amplitude of the wanted carrier.

It will be seen from Fig. 1 that, in the case of negative modulation, the combined rectification effects of the detector and the c.r.t. can produce a reversal in the polarity of $\Delta B/B \times 1/u^2$. At low values of the picture-signal, E, (which correspond to relatively large values of carrier amplitude) the c.r.t. characteristic produces the greater effect; at values of E greater than 0·65 the effect of the envelope detector predominates.

Fig. 2 shows the modulus of the fractional brightness change, plotted against the normalized picture brightness level, B/B_{max}, for $u = 0{\cdot}1$; this corresponds to a 20 dB ratio between the amplitudes of wanted and interfering signals and, for positive modulation, represents a secondary pattern of "just tolerable" severity. It will be seen that, over the middle portion of the grey scale, the visibility of the secondary patterns is much less for negative-modulation receivers. The extent to which the modulation polarity affects the visibility of the interference obviously depends greatly on the distribution of the large-area grey tones in the received picture. Subjective tests, using typical pictures, showed that for a given visibility, interference could be increased by about 6 dB when negative modulation was employed.

Fig. 3 shows photographs of secondary patterns on negative- and positive-modulation receiver displays; the receivers were fed with wanted signals representing line sawtooth waveforms and an interfering carrier which was switched on and off at about twenty times the field-scan frequency. In the absence of the interference the wanted signal produced a full range of grey levels, the displays being dark at the left and white at the right. In Fig. 3, the interference shows as horizontal bands of increased brightness on the positive-modulation display and bands of in-

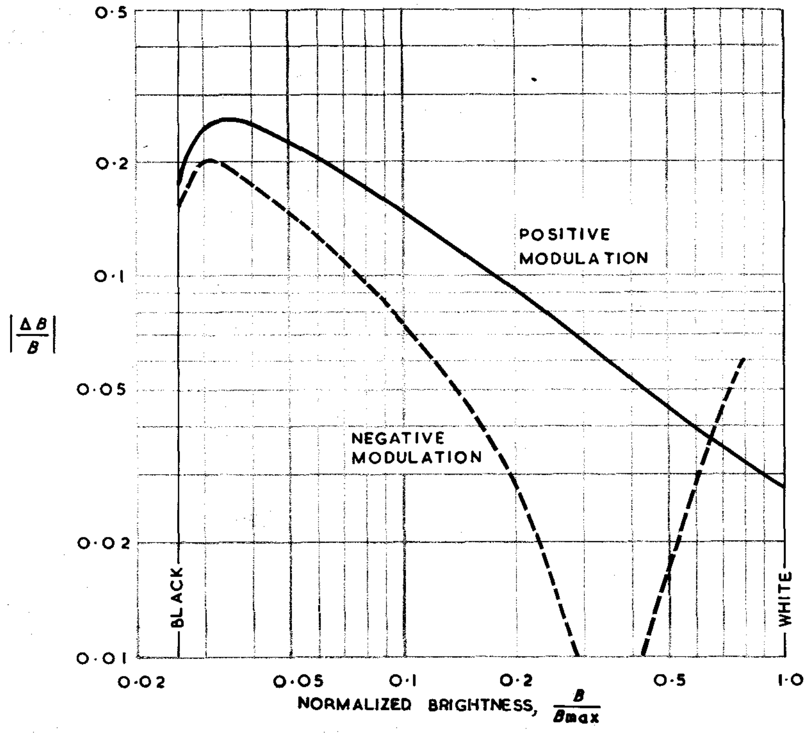

Fig. 2 - Fractional brightness-difference as a function of normalized brightness for $u = 0{\cdot}1$

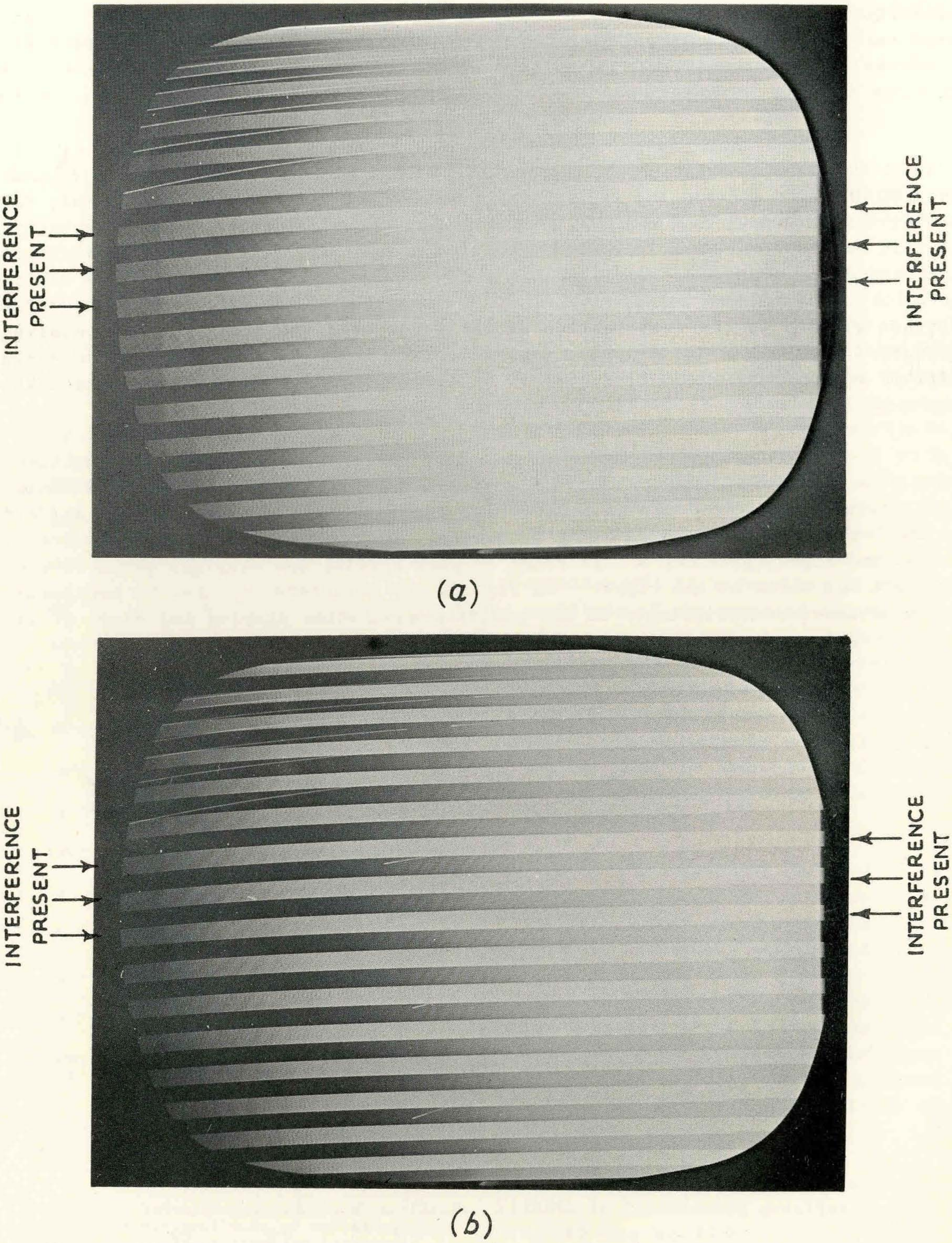

Fig. 3 - The effect of secondary interference on negative- and positive-modulation systems

(*a*) negative modulation (*b*) positive modulation creased brightness on only the left half of the negative-modulation display. The visibility of the interference diminishes to zero near the centre of the negative-modulation display and it is visible as bands of reduced brightness in the right half; this could be predicted from the polarity reversal of $\Delta B/B \times 1/u^2$ shown in Fig. 1.

3. CONCLUSIONS

It has been shown that the visibility of the secondary interference pattern produced by the inherent non-linearity of television receivers using envelope detectors is somewhat less for negative-modulation than for positive-modulation receivers. The effect of this is that the maximum advantage of precision control of the offset frequency in reducing the visibility of co-channel interference is less (about 6 dB) for positive-modulation systems than for negative-modulation systems.

This reduction of interference cannot be considered as a major factor in the choice of modulation polarity, particularly at u.h.f., because of the practical difficulties of controlling the "offset" with sufficient precision. It is, however, an advantage for negative modulation which may prove useful if more precise control of carrier frequencies becomes possible.

4. ACKNOWLEDGEMENTS

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